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REVIEW

Nutritional and health properties of pulses

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Abstract Pulses represent one of the most important food categories that have been extensively used as staple foods to cover basic protein and energy needs throughout the history of humanity. In addition to their low lipid and high dietary fibre content, emerging evidence stresses the importance of pulses as carriers of several constituents of potential biological importance, including enzyme inhibitors, lectins, phytates, oxalates, polyphenols, saponins and phytosterols. Investigations in humans suggest that pulses may contribute to human health and well-being, mostly through prevention of coronary heart disease and possibly diabetes. The mechanisms responsible for this apparently protective role may include a favourable influence on blood lipids and glucose. The nutritional value of pulses, which are a key component of the traditional Mediterranean diet, is not generally recognised and is frequently under-appreciated.

Keywords Pulses · Nutritional composition · Phytochemicals · Coronary heart disease

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Introduction

From the more than 15,000 legume species of the Fabaceae (or Leguminosae) family, only a few are part of our diet. These are commonly referred to as "pulses", a term probably deriving from the Latin *puls* meaning pottage, while the term "legume" originates from the Latin *legumen* describing seeds harvested from pods [1]. Pulses have constituted an important food category for humans for thousands of years and are typically incorporated in various forms into most traditional diets around the globe. As a food group, pulses have several appealing attributes including their high nutritional value, low cost and long preservation periods outside the cold chain. Pulses make an important contribution in terms of protein and energy provision to populations in the developing world. Other attractive characteristics include their high dietary fibre and low lipid content, as well as the presence of various biologically active compounds. However, the long preparation time required as well as their propensity to cause flatulence may both contribute to a decreased consumer demand.

The Food and Agriculture Organization of the United Nations (FAO) defines pulses as "annual leguminous crops yielding from one to twelve grains or seeds of variable size, shape and colour within a pod" [2]. The definition includes crops used for both food and feed and covers 11 primary pulses (dry beans, dry broad beans, dry peas, chickpeas, dry cow peas, pigeon peas, lentils, bambara beans, vetches, lupins and pulses nes) and 2 pulse products (flour and bran of pulses), but excludes legumes harvested green for food (e.g., green beans), as well as crops used for sowing purposes (e.g., alfalfa seeds) or for oil extraction (e.g., soybean). In this article the scientific literature on pulses is reviewed with particular focus on

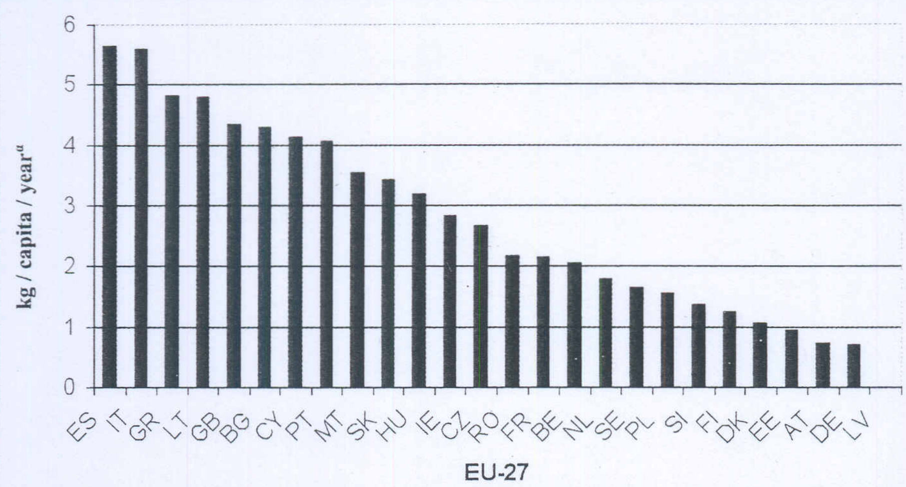

Fig. 1 Average availability of pulses (year 2003) in European Union countries (EU-27, no data available for Luxemburg) [6]. ªBeans + Peas + Other Pulses (expressed on a raw weight basis)

their nutritional composition and importance to human health. Following the FAO's definition, legumes such as green beans, soybeans and peanuts are not considered in this paper.

Production and consumption

At the international level, about half of bean and three quarters of lentil production occurs in Asia; 80% of pea production takes place in China and Russia, while India is the major chickpea producer [3]. The Indian subcontinent represents the leading area in terms of pulse consumption [4]. Production in the European Union (EU-15, 1999–2000 data) encompasses peas, broad beans, vetches, dry beans, chickpeas, lupins and lentils, while consumption covers beans (41%), dry peas (21%), lentils (14%), fava beans (13%) and chickpeas (11%) [4]. The average per capita availability among the current 27 European Union members is presented in Figure 1 (2003 data). The higher availability observed in the Mediterranean countries may be partly explained by the wide use of olive oil in the Mediterranean region, which has been shown to facilitate the ample consumption of vegetables and pulses [5].

Nutritional composition

Macro- and micronutrients

The nutrient and energy content of some of the most important pulses is presented in Table 1. Pulses provide a rich source of protein. However, the quality of the protein is inferior to that of animal products because of the limiting amounts of sulphuric amino acids, the resistance to proteolysis due to the nature of the seed and the presence of other compounds with a potential to reduce the bioavailability of proteins [7]. The human body can utilise between about 32% and 78% of the protein from pulses ingested [1]. However, pulses have traditionally been consumed along with cereals, which are relatively rich in sulphuric amino acids while deficient in lycine. Pulses are generally high in lycine, and therefore, when combined with cereals, dishes of good protein quality are obtained.

In addition to their high protein content, pulses contain large amounts of complex carbohydrates, predominantly starch and dietary fibre, as well as appreciable quantities of vitamins (mostly of the B group) and inorganic compounds such as Fe, Mg, Zn and P. The extent to which such micronutrients are available for the physiological processes of the human organism is variable. For example, the iron bioavailability of black beans, lentils, mung beans and split pea soups in humans was found to be 0.84%, 1.20%, 1.91% and 1.09% of the amounts ingested, respectively [10].

Another important consideration is that common household preparation procedures, such as soaking and cooking, generally reduce the content of several nutrients such as minerals, vitamins and some amino acids as well as various non-nutrient components [11–13]. The latter are also thought to be involved in various biological functions in the human organism. The content of some of these compounds in some pulses is shown in Table 2. These are briefly discussed in the following paragraphs.

Enzyme inhibitors and other proteins

Pulses contain various protein molecules that can exert a broad range of biological actions in the human body, including both favourable and undesirable ones.

Table 1 Nutritional composition per 100 g of raw pulses [8, 9]

Component	White beans	Lentils	Chickpeas	Broad beans
Energy and proximates				
Energy (kcal)	286	297	320	245
Water (g)	11.3	10.8	10.0	11.0
Protein (g)	21.4	24.3	21.3	26.1
Total lipids (g)	1.6	1.9	5.4	2.1
SFA (g)	0.3	0.2	0.5	0.3
MUFA (g)	0.4	0.3	1.1	0.3
PUFA (g)	0.5	0.8	2.7	1.1
Cholesterol (mg)	0	0	0	0
Carbohydrate (g)	49.7	48.8	49.6	32.5
Starch (g)	42.7	44.5	43.8	24.4
Total sugars (g)	2.8	1.2	2.6	5.9
Dietary fibre (g)	17	8.9	10.7	27.6
Inorganic compounds				
Na (mg)	43	12	39	11
K (mg)	1160	940	1000	1090
Ca (mg)	180	71	160	100
Mg (mg)	180	110	130	190
P (mg)	310	350	310	590
Fe (mg)	6.7	11.1	5.5	5.5
Zn (mg)	2.8	3.9	3	3.1
Vitamins				
Retinol (g)	0	0	0	0
Carotene (g)	Tr	N	60	N
Vitamin E (mg)	0.21	N	2.88	N
Thiamin (mg)	0.45	0.41	0.39	0.5
Riboflavin (mg)	0.13	0.27	0.24	0.26
Vitamin B6 (mg)	0.56	0.93	0.53	0.37
Vitamin C (mg)	Tr	Tr	Tr	Tr

N No data, *Tr* traces

Table 2 Compounds and indexes of pulses with biological importance

Class/compound	Lentils	Chickpeas	White Beans	Broad beans
Phenolic compounds				
Tannins (% of dm[a]) [14]	0.1	0–0.1	0–0.7	0–2.1
Lignans (mg/100 g) [14]	1.8	N	0.3	N
Daidzein (mg/100 g) [15]	0	0.04	0	0.02
Genistein (mg/100 g) [15]	0	0.06	0.74	0
Total proanthocyanidins (mg/100 g) [16]	1.84	0	0.13	154.45
Total phenols (mg GAE[b]/100 g) [17]	628	90	94	N
Phytosterols				
Campesterol (mg/100 g) [18]	10	12.4	4	N
Stigmasterol (mg/100 g) [18]	10.8	8.3	35.2	N
β-Sitosterol (mg/100 g) [18]	80.8	84.1	56.3	N
Stigmastanol (mg/100 g) [18]	8.4	10.5	1	N
Total phytosterols (mg/100 g) [19]	N	N	N	124
Carbohydrates				
Resistant starch (g/100 g) [20]	3.3	3.4	N	N
Raffinose (% of dm) [21]	0.3–1	0.4–1.2	<0.05–0.93	0.1–0.3
Stachyose (% of dm) [21]	1.7–3.1	2–3.6	0.5–4.1	0.7–1.5
Verbascose (% of dm) [21]	0.6–3.1	0.6–4.2	0.06–4	1.7–3.1
Other compounds+indexes				
Oxalates (% of dm) [14]	0.16	0.07	0.1–0.5	N
Phytic acid (g/100 g) [9]	0.49	0.5	0.8	1.28
Saponins (g/100 g) [22]	0.37	5	1.6	0.4
Glycaemic index (boiled samples) [23]	29	28	38	N
Total ORAC[c] (μmolTE[d]/100 g) [17]	7282	847	1520	N

[a]Dry matter, [b]gallic acid equivalents, [c]oxygen radical absorbance capacity, [d]trolox equivalents
N no data

Protease inhibitors are a very important category of proteins found in pulses and these may cause reduced absorption of other proteins. Since protease inhibitors are largely denatured while cooking, a result that minimises their inhibitory effects, much research has been driven towards clarifying other physiological actions these may trigger. Protease inhibitors have been investigated in relation to the development of pancreatic cancer and an aetiological relationship has been considered [24]. However, the ecological evidence of an increased incidence of pancreatic cancer in populations with high intake of foods rich in protease inhibitors is far from convincing [25].

Attention has also been focused on the potential anticancer properties of the Bowman-Birk protease inhibitor (BBI) found in soybeans and many other legume seeds such as lentils, chickpeas, peas and several types of beans [26]. Other potentially beneficial attributes of the BBI include anti-inflammatory activity and likely effects against obesity and several degenerative and autoimmune diseases [7].

Lectins (or haemagglutinins) are glycoproteins that agglutinate red blood cells. They can bind to specific receptor sites on the epithelial cell wall of the small intestine and cause impaired absorption of several nutrients such as sugars, amino acids, lipids and vitamin B12. In addition, lectins may reduce the activity of digestive enzymes or damage the intestinal mucosa, allowing bacteria to enter into circulation [25]. However, evidence of an anticarcinogenic effect of lectins has also been reported [27]. It is important to note that the activity of lectins is sharply reduced during common heat treatment procedures applied to pulses [13, 28]. α-Amylase inhibitors present in pulses can reduce starch digestion but research on the effects of α-amylase inhibitors in a broader health context is still inconclusive [13, 25]. Also, pure broad bean and lupin protein extracts exert hypocholesterolaemic effects [29, 30].

Phytic acid

Phytic acid (inositol hexaphosphate) is a phosphated carbohydrate, important for regulating various functions of human cells. Most research has focused on its purported anticancer properties and it has been hypothesised that phytic acid may be responsible for the anticarcinogenic effects of dietary fibre [31]. Phytic acid acts as an effective antioxidant by creating complexes with Fe, thus preventing hydroxyl radical generation (Fenton reaction) and lipid peroxidation [32]. The latter attribute has been proposed as relevant to its possible anticancer action [33]. Besides Fe, phytic acid also binds to Zn and Ca, thus reducing the bioavailability of these minerals [14]. Common cooking practices reduce, but do not eliminate, the phytic acid content of pulses [12, 34, 35].

Oxalates

Calcium oxalate is the major constituent of kidney stones. Stone formation is associated with increased urinary oxalate, the latter being affected to an important extend by dietary oxalate [36]. In this context, dietary management has been proposed as an appropriate strategy towards the prevention and management of renal lithiasis [36, 37]. Oxalic acid also tends to reduce the bioavailability of Ca, but the research on issue is still ongoing [38]. Cooked pulses contain measurable amounts of oxalate [39].

Phenolic compounds

A major characteristic of phenolic compounds is their antioxidant activity, an effect that has been proposed to play a key role in countering the process of ageing and the development of various degenerative diseases [40]. Various important classes of phenolic compounds, such as tannins, isoflavones and lignans, have been reported to be present in pulses [14]. In addition to their antioxidant properties, isoflavones and lignans exert a weak oestrogenic activity, which may be implicated in several mechanisms protecting the human body [41]. Phenols, however, can also be responsible for reduced mineral (mainly Fe) bioavailability [42]. The concentration of isoflavones and lignans in pulses is generally low, while that of tannins is considerably higher [14, 15]. Tannin losses due to common cooking of pulses appear to be in the order of 40–50% [12, 35].

Saponins

Saponins are glucosides of a steroid or a triterpenoid group and owe many of their actions to their amphiphilic nature. Both detrimental and beneficial health properties have been attributed to saponins. They can cause lysis of red blood cells and also cells found in the intestinal mucosa, and may also reduce the absorption of nutrients either directly by binding or by inactivating enzymes involved in the digestion process [25]. On the other hand, saponins may bind with cholesterol or bile acids, thus increasing faecal cholesterol excretion. The latter can result in lower blood cholesterol levels [25, 43]. Also, evidence suggests that saponins may exert anticarcinogenic effects through various mechanistic pathways [20, 25]. Saponin losses due to preparation/cooking procedures are generally small [20, 28].

Phytosterols

Much research has been dedicated to the hypocholesterolaemic effects of plant sterols, stanols and their esters. For example, it was shown that preparations such as margarines or yoghurts fortified with esterified stanols at a daily dose of about 2–3 g can provide an effective dietary means to reduce serum low-density lipoprotein cholesterol (LDL-C) concentration by about 14% [44, 45]. The sterol content of pulses is in the order of about 100 mg/100 g (see Table 2) and pulses provide one of the best natural sources of phytosterols [19]. Therefore, the contribution of phytosterols to the apparent cholesterol-reducing capacity of pulses may be very important (see section on cardiovascular disease below).

Oligosaccharides

Raffinose, stachyose and verbascose, all galactosides of sugar, are the most important oligosaccharides found in pulses [21]. Since humans do not express α-galactosidase to break down such compounds, these are eventually fermented in the large bowel to produce mainly short-chain fatty acids and gas. Soaking and common cooking procedures may reduce postprandial gas production by eliminating their oligosaccharide content [35]. Oligosaccharides are currently being investigated for their potential to exert prebiotic activities; the results are promising, but the results are not yet clear [21, 46].

Pulses and chronic disease

Cardiovascular disease

The literature consistently indicates a link between regular pulse consumption and a favourable management of serum total cholesterol (TC) and LDL-C concentrations, well known biomarkers for coronary heart disease (CHD) risk. For example, in a trial involving 9 healthy men, consumption of 120 g (dry weight) of beans, peas and lentils on a daily basis for a 6–7-week period increased cholesterol saturation of gallbladder bile, secretion of biliary cholesterol and faecal acidic sterol output, all of which contributed to a better (negative) cholesterol balance [47]. Anderson and Major [48] meta-analysed the evidence from 11 clinical trials assessing the impact of pulse consumption on fasting serum lipoproteins (the quantities consumed daily in these studies ranged between 46 and 150 g (uncooked pulses)). The authors concluded that regular pulse consumption produces overall significant reductions in TC (7.2%) and LDL-C (6.2%). Triacylglycerols were also reduced while high-density lipoprotein cholesterol was unaffected. More recent clinical studies also support these findings [49, 50].

There is also promising observational evidence on the role of pulses in the aetiology of chronic diseases, but further investigations will be essential to address the issue adequately [51]. In a prospective cohort study among 9632 US men and women, a significant inverse association between legume consumption and CHD incidence (22%) was shown [52]. Furthermore, legumes and oils were the only food groups negatively linked to the 25-year age-adjusted mortality from CHD in the Seven Countries Study [53]. More recently, legume consumption was inversely associated with overall and cardiovascular mortality, but not with cancer, in a cohort of about 10,000 diabetic European participants [54]. The factors contributing to the hypocholesterolaemic effect of pulses could include one or more of the following: soluble dietary fibre, vegetable protein, oligosaccharides, isoflavones, phospholipids, fatty acids, phytosterols and saponins [48].

Diabetes

The glycaemic index has been defined as "the incremental area under the blood glucose response curve of a 50g carbohydrate portion of a test food expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject" [55]. The glycaemic load from a diet may impact the metabolism of carbohydrate and lipids, which in turn could trigger diabetes and CHD. For example, a collective analysis of 11 studies showed that a low-GI diet reduces mean blood glucose (16%), blood glycosylated haemoglobin (9%), urinary C-peptide (20%), TC (6%) and triacylglycerols (9%) [56].

In the pioneering studies of Jenkins and colleagues [57, 58] on the impact of dietary sources on the postprandial glucose increase in healthy or diabetic individuals, the investigators characterised pulses as "remarkable in how little they raised the blood glucose". In fact, pulses showed the lowest mean glycaemic index among several other food groups including dairy products, fruits, biscuits, cereals and breakfast cereals, vegetables, sugars and root vegetables [57]. Thomson [25] suggested that the mechanisms through which several pulse components such as phytates, tannins, lectins and amylase inhibitors may potentially flatten blood glycaemic response include: (a) direct binding with α-amylase compromising starch digestion, (b) binding with Ca (phytates and tannins), which is required for the stabilisation of amylase activity, (c) binding with starch (phytates and tannins), affecting the degree of gelatinisation or accessibility to enzymes, (d) slowing gastric emptying (phytates) and (e) binding to the intestinal mucosal cells (lectins) affecting the absorption of nutrients. The overall evidence suggests that nutritional advice for the prevention of diabetes should primarily include the ample consumption of pulses as well as other whole grain foods [59].

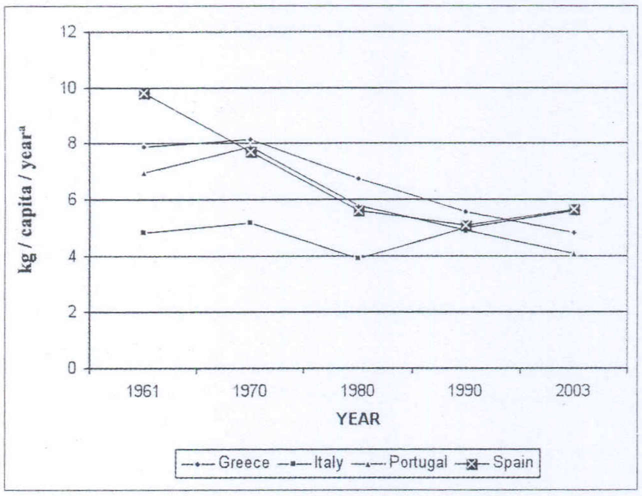

Fig. 2 Trends in availability of pulses in Mediterranean countries [6]. [a]Beans + Peas + Other Pulses (expressed on a raw weight basis)

Cancer

Generally, the epidemiological evidence on the role of the consumption of pulses in the development of cancer is sparse, probably due to the diversity of pulses available, the low amounts consumed by most population groups and the variety of methods of preparation among different cultures [60]. The expert panel of the World Cancer Research Fund/American Institute for Cancer Research in a recent report [61] suggested that there is no convincing or probable link between the consumption of pulses and any of the 17 cancer sites investigated. It should be noted, however, that a number of compounds present in pulses, such as resistant starch, non-starch polysaccharides, oligosaccharides, folate, selenium, zinc, protease inhibitors, saponins, phytosterols, lectins and phytates, have been shown to have an anticarcinogenic role [60].

Pulses, traditional Mediterranean diet and longevity

The traditional Mediterranean diet reflects the dietary practices of the inhabitants of the olive-growing Mediterranean regions in the 1960s. One of its defining characteristics is the high consumption of pulses [62]. Pulses have been an important element of the Mediterranean gastronomy for thousands of years. They are consumed in a variety of ways, principally as a main dish, such as in the form of porridge [63], but also as a salad or incorporated in various side dishes. Pulses are traditionally prepared with olive oil, commonly supplemented with herbs and vegetables, while the resulting dishes are usually complemented with bread. The latter uses provide additional importance to the nutritional value of pulses. Studies in Greece [64], other Mediterranean countries [65, 66] and other European countries [67–69], but also in Australia [70] and the USA [71] have all documented a beneficial role of the traditional Mediterranean diet on longevity. The relative importance of the individual compounds of this diet has not been ascertained, mostly because of interactive effects. However, it is believed that pulses play an intrinsically crucial role in the health impact of the Mediterranean diet and the longevity of populations in the Mediterranean region [5]. Although today consumption has decreased (Fig. 2), pulses still have an important place on the Mediterranean table.

Nutrition and health claims for pulses

The new EU regulation

The recently released European regulation on nutrition and health claims made for foods lays the conditions that should be applied for the use of such claims in the commercial communication of foods within the European Union [72]. In the case of nutrition claims, only claims already listed in the regulation can be used, provided that the food complies with the general requirements of the regulation and the specific conditions applying for the claim. Also, in order to use a claim, the relevant food or food group should be in accordance with a specific nutrient profile to be defined later by the European Commission (EC).

At this early stage, it is apparent that pulses have a favourable nutritional composition in terms of their eligibility to bear some of the listed nutrition claims. The regulation distinguishes two categories of health claims: (a) those referring to the reduction of disease risk or to children's development and health and (b) claims used mainly to describe the role of foods or their constituents in physiological and psychological functions, as well as claims referring to weight management. To be eligible to bear a health claim under the first category, an application for authorisation must be submitted to the European Commission; this should include information on, among other things, the substance/food/food category to bear the claim as well as scientific studies substantiating the health claim.

Pulses and CHD

A health claim on the relationship between pulses and CHD would mean that there is enough evidence that consumption of pulses significantly reduces the incidence or a risk factor involved in the development of CHD. When relevant health claim petitions on the association between foods and CHD were made in the USA, the responsible authorities took under consideration mainly human intervention studies on the effect of the foods on TC and LDL-C levels [73]. Overall, the evidence on the role of pulses against CHD is strongly suggestive and a health claim under the new EC regulation may be realistic. The reductions in TC and LDL-C induced by pulse consumption (see section on cardiovascular disease above) are particularly important since it has been shown that a 10% reduction in serum TC concentration can substantially lower ischaemic heart disease incidence [74], while each 1% reduction of LDL-C reduces by 1% the risk of developing the disease [75]. Anderson and Major [48] suggested that a health claim on pulses could be feasible in the USA and proposed a possible format of the claim: "The daily intake of dry beans as part of a diet low in saturated fat and cholesterol may decrease risk of coronary heart disease". In order to obtain a clearer view however, additional epidemiological studies and clinical trials are needed.

Conclusions

Pulses are natural plant foods that have traditionally been consumed by various populations around the world since antiquity. They can be therefore perceived as safe by the contemporary consumer, while supportive scientific knowledge on their nutritional properties has already been obtained. Their nutritional profile merits special attention from health professionals, food manufacturers and policy makers when planning strategies or public health nutrition campaigns. Pulses could be an important part of a healthy diet on the basis of their low content of sugars and fat (and zero cholesterol), high amounts of protein and fibre, and the presence of various phytochemicals, many of which may beneficially affect health.

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References

1. Grusak MA (2005) Legumes. In: Caballero B, Allen L, Prentice A (eds) Encyclopedia of human nutrition. Academic Press, New York
2. FAO (1994) Definition and classification of commodities (draft). http://www.fao.org/WAICENT/faoinfo/economic/faodef/FAODEFE.HTM (Accessed Aug 2008)
3. Dalgetty DD, Baik B-K, Swanson BG (2003) Pulses. In: Caballero B, Trugo L, Finglas PM (eds) Encyclopedia of food sciences and nutrition. Academic Press, London
4. Schneider AVC (2002) Overview of the market and consumption of pulses in Europe. Br J Nutr 88[Suppl 3]:243–250
5. Vasilopoulou E, Georga K, Bjoerkov Joergensen M et al (2005) The antioxidant properties of Greek foods and the flavonoid content of the Mediterranean menu. Curr Med Chem 5:1–13
6. FAO (2003) FAOSTAT. Food Balance Sheets. http://faostat.fao.org/site/502/default.aspx (Accessed March 2008)
7. Duranti M (2006) Grain legume proteins and nutraceutical properties. Fitoterapia 77:67–82
8. Trichopoulou A, Georga K (2004) Composition tables of foods and Greek dishes, 3rd edn. Parisianou Publications, Athens
9. The Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food (1991) Fifth Supplement (Vegetables, Herbs and Spices) to McCance and Widdowson's The Composition of Foods, 4th edn. Royal Society of Chemistry, Cambridge
10. Lynch SR, Beard JL, Dassenko SA et al (1984) Iron absorption from legumes in humans. Am J Clin Nutr 40:42–47
11. Barampama Z, Simard RE (1995) Effects of soaking, cooking and fermentation on composition, in-vitro starch digestibility and nutritive value of common beans. Plant Foods Hum Nutr 48:349–365
12. El-Adawy TA (2002) Nutritional composition and antinutritional factors of chickpeas (Cicer arietinum L.) undergoing different cooking methods and germination. Plant Foods Hum Nutr 57:83–97
13. Lajolo FM, Genovese MI (2002) Nutritional significance of lectins and enzyme inhibitors from legumes. J Agric Food Chem 50:6592–6598
14. Champ MM-J (2002) Non-nutrient bioactive substances of pulses. Br J Nutr 88[Suppl 3]:307–319
15. U.S. Department of Agriculture (2007) USDA-Iowa State University Database on the isoflavone content of foods. Release 1.4, April 2007. http://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/isoflav/isoflav1-4.pdf (Accessed March 2008)
16. U.S. Department of Agriculture (2004) Database for the proanthocyanidin content of selected foods. August 2004. http://www.nal.usda.gov/fnic/foodcomp/Data/PA/PA.pdf (Accessed April 2008)
17. US Department of Agriculture (2007) Oxygen radical absorbance capacity (ORAC) of selected foods. November 2007. http://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/ORAC/ORAC07.pdf (Accessed March 2008)
18. Jimenez-Escrig A, Santos-Hidalgo AB, Saura-Calixto F (2006) Common sources and estimated intake of plant sterols in the Spanish diet. J Agric Food Chem 54:3462–3471

19. US Department of Agriculture (2007) National nutrient database for standard reference, Release 20. http://www.nal.usda.gov/fnic/foodcomp/search/ (Accessed March 2008)
20. Rochfort S, Panozzo J (2007) Phytochemicals for health, the role of pulses. J Agric Food Chem 55:7981–7994
21. Guillon F, Champ MM-J (2002) Carbohydrate fractions of legumes: uses in human nutrition and potential for health. Br J Nutr 88[Suppl 3]:293–306
22. Fenwick DE, Oakenfull D (1983) Saponin content of food plants and some prepared foods. J Sci Food Agric 34:186–191
23. Foster-Powell K, Holt SHA, Brand-Miller JC (2002) International table of glycemic index and glycemic load values. Am J Clin Nutr 76:5–56
24. Hathcock JN (1991) Residue trypsin inhibitor: data needs for risk assessment. Adv Exp Med Biol 289:273–279
25. Thompson LU (1993) Potential health benefits and problems associated with antinutrients in foods. Food Res Int 26:131–149
26. Losso JN (2008) The biochemical and functional food properties of the Bowman-Birk inhibitor. Crit Rev Food Sc Nutr 48:94–118
27. Pryme IF, Bardocz S, Pusztai A et al (1999) The growth of an established murine non-Hodgkin lymphoma tumour is limited by switching to a phytohaemagglutinin-containing diet. Cancer Lett 146:87–91
28. Gupta YP (1987) Anti-nutritional and toxic factors in food legumes: a review. Plant Foods Hum Nutr 37:201–228
29. Weck M, Hanefeld M, Leonhardt W et al (1983) Field bean protein diet in hypercholesteremia. Nahrung 27:327–333
30. Sirtori CR, Lovati MR, Manzoni C et al (2004) Proteins of white lupin seed, a naturally isoflavone-poor legume, reduce cholesterolemia in rats and increase LDL receptor activity in HepG2 cells. J Nutr 134:18–23
31. Graf E, Eaton JW (1985) Dietary suppression of colonic cancer. Fiber or phytate? Cancer 56:717–718
32. Graf E, Empson KL, Eaton JW (1987) Phytic acid. A natural antioxidant. J Biol Chem 262:1647–1650
33. Vucenic I, Shamsuddin AM (2006) Protection against cancer by dietary IP6 and inositol. Nutr Cancer 55:109–125
34. Khalil MM (2001) Effect of soaking, germination, autoclaving and cooking on chemical and biological value of guar compared with faba bean. Nahrung/Food 45:246–250
35. Ibrahim SS, Habiba RA, Shatta AA et al (2002) Effect of soaking, germination, cooking and fermentation on antinutritional factors in cowpeas. Nahrung/Food 46:92–95
36. Massey LK (2007) Food oxalate: factors affecting measurement, biological variation, and bioavailability. J Am Diet Assoc 107:1191–1194
37. Grases F, Costa-Bauza A, Prieto RM (2006) Renal lithiasis and nutrition. Nutr J 5:23
38. Heaney RP, Weaver CM (1989) Oxalate: effect on calcium absorbability. Am J Clin Nutr 50:830–832
39. Chai W, Liebman M (2005) Oxalate content of legumes, nuts, and grain-based flours. J Food Comp Anal 18:723–729
40. Harman D (1956) Aging: a theory based on free radical and radiation chemistry. J Geront 11:298–300
41. Barnes S, Boersma B, Patel R et al (2000) Isoflavonoids and chronic disease: mechanisms of action. Biofactors 12:209–215
42. Sandberg A-S (2002) Bioavailability of minerals in legumes. Br J Nutr 88[Suppl 3]:281–285
43. Sidhu GS, Oakenfull DG (1986) A mechanism for the hypocholesterolaemic activity of saponins. Br J Nutr 55:643–649
44. Miettinen TA, Puska P, Gylling H et al (1995) Reduction of serum cholesterol with sitostanol-ester margarine in a mildly hypercholesterolemic population. N Engl J Med 16:1308–1312
45. Mensink RP, Ebbing S, Lindhout M et al (2002) Effects of plant stanol esters supplied in low-fat yoghurt on serum lipids and lipoproteins, non-cholesterol sterols and fat soluble antioxidant concentrations. Atherosclerosis 160:205–213
46. Mussatto SI, Mancilha IM (2007) Non-digestible oligosaccharides: a review. Carbohydrate Polymers 68:587–597
47. Duane WC (1997) Effects of legume consumption on serum cholesterol, biliary lipids, and sterol metabolism in humans. J Lipid Res 38:1120–1128
48. Anderson JW, Major AW (2002) Pulses and lipaemia, short- and long-term effect: Potential in the prevention of cardiovascular disease. Br J Nutr 88[Suppl 3]:263–271
49. Pittaway JK, Ahuja KD, Robertson IK et al (2007) Effects of a controlled diet supplemented with chickpeas on serum lipids, glucose tolerance, satiety and bowel function. J Am Coll Nutr 26:334–340
50. Winham DM, Hutchins AM, Johnston CS (2007) Pinto bean consumption reduces biomarkers for heart disease risk. J Am Coll Nutr 26:243–249
51. Kushi LH, Meyer KA, Jacobs DR Jr (1999) Cereals, legumes, and chronic disease risk reduction: evidence from epidemiologic studies. Am J Clin Nutr 70[Suppl]:451–458
52. Bazzano LA, He J, Ogden LG et al (2001) Legume consumption and risk of coronary heart disease in US men and women. Arch Int Med 161:2573–2578
53. Menotti A, Kromhout D, Blackburn H et al (1999) Food intake patterns and 25-year mortality from coronary heart disease: cross-cultural correlations in the Seven Countries Study. Eur J Epidemiol 15:507–515
54. Nothlings U, Schulze MB, Weikert C et al (2008) Intake of vegetables, legumes, and fruit, and risk for all-cause, cardiovascular, and cancer mortality in a European Diabetic population. J Nutr 138:775–781
55. FAO/WHO (1998) Carbohydrates in human nutrition. Report of a Joint FAO/WHO Expert Consultation. FAO Food and Nutrition Paper 66:1–129
56. Miller JCB (1994) Importance of glycemic index in diabetes. Am J Clin Nutr 59S:747–752
57. Jenkins DJA, Wolever TMS, Taylor RH et al (1981) Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr 34:362–366
58. Jenkins DJA, Wolever TMS, Jenkins AL et al (1983) The glycaemic index of foods tested in diabetic patients: A new basis for carbohydrate exchange favouring the use of legumes. Diabetologia 24:257–264
59. Venn BJ, Mann JI (2004) Cereal grains, legumes and diabetes. Eur J Clin Nutr 58:1443–1461
60. Mathers JC (2002) Pulses and carcinogenesis: potential for the prevention of colon, breast and other cancers. Br J Nutr 88[Suppl 3]:273–279
61. World Cancer Research Fund/American Institute for Cancer Research (2007) Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective. AICR, Washington DC
62. Trichopoulou A, Lagiou P (1997) Healthy traditional Mediterranean diet – an expression of culture, history and lifestyle. Nutr Rev 55:383–389
63. Miha-Lampaki A (1984) The diet of the ancient Greeks according to ancient comedy writers. Doctoral Thesis, Athens
64. Trichopoulou A, Costacou T, Bamia C et al (2003) Adherence to a Mediterranean diet and survival in a Greek population. N Engl J Med 348:2599–2608
65. Esposito K, Marfella R, Ciotola M et al (2004) Effect of a Mediterranean-style diet on endothelial dysfunction and markers of vascular inflammation in the metabolic syndrome. JAMA 292:1440–1446
66. Martínez-González MA, de la Fuente-Arrillaga C, Nunez-Cordoba JM et al (2008) Adherence to Mediterranean diet and risk of developing diabetes: prospective cohort study. BMJ 336:1348–1351

67. Trichopoulou A, Orfanos P, Norat T et al (2005) Modified-Mediterranean diet and survival: the EPIC-Elderly prospective cohort study. BMJ 330:991–997
68. Lagiou P, Trichopoulos D, Sandin S et al (2006) Mediterranean dietary pattern and mortality among young women: a cohort study in Sweden. Br J Nutr 96:384–392
69. Knoops KT, de Groot LC, Kromhout D et al (2004) Mediterranean diet, lifestyle factors, and 10-year mortality in elderly European men and women: the HALE project. JAMA 292:1433–1439
70. Kouris-Blazos A, Gnardellis C, Wahlqvist ML et al (1999) Are the advantages of the Mediterranean diet transferable to other populations? A cohort study in Melbourne, Australia. Br J Nutr 82:57–61
71. Mitrou PN, Kipnis V, Thiebaut AC et al (2007) Mediterranean dietary pattern and prediction of all-cause mortality in a US population: results from the NIH-AARP diet and health study. Arch Intern Med 167:2461–2468
72. The European Parliament and the Council of the European Union (2006) Corrigendum to Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Of J Eur Union L12:3–18
73. US Food and Drug Administration, Department of Health and Human Services (2004) Letter responding to health claim petition dated August 28, 2003: monounsaturated fatty acids from olive oil and coronary heart disease (Docket No 2003Q-0559). http://www.cfsan.fda.gov/~dms/qhcolive.html (Accessed March 2008)
74. Law MR, Wald NJ, Thompson SG (1994) By how much and how quickly does reduction in serum cholesterol concentration lower risk of ischaemic heart disease? BMJ 308:367–372
75. Robinson JG, Smith B, Maheshwari N et al (2005) Pleiotropic effects of statins: Benefit beyond cholesterol reduction? J Am Coll Cardiol 46:1855–1862